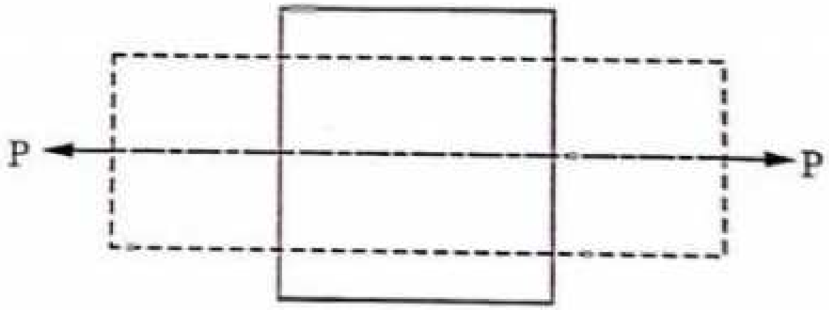
SIMPLE STRESSES AND STRAINS

2.1 LOAD

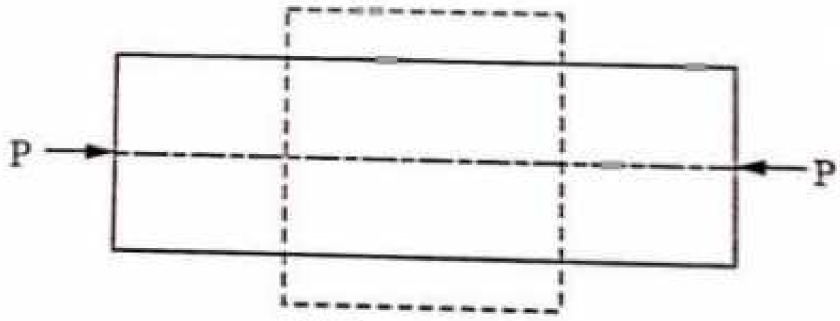
Any external force acting on a body is called load. The units of load are same as that of force. In S.I. system, load is measured in Newton (N).

2.2 EFFECT OF LOAD ON A BODY

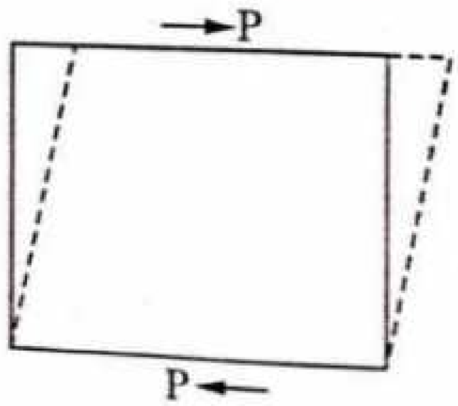
When a load is applied on a body, the shape and size of the body get changed depending upon the nature of the applied load as shown below :



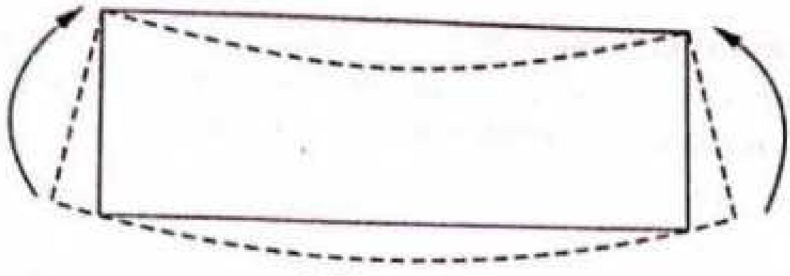
(*a*) Tension



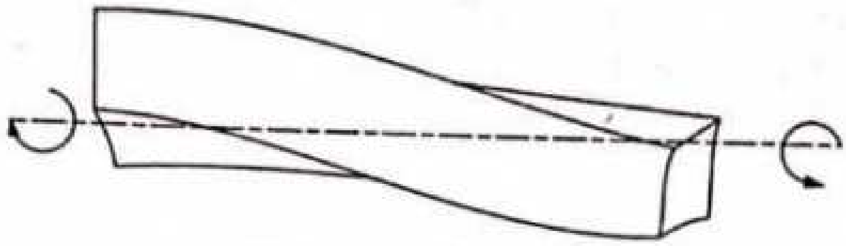
(*b*) Compression



(c) Shearing



(d) Bending



(e) Torsion (Twisting)

Fig. 2.1 : Effect of Load on A Member

2.3 CLASSIFICATION OF LOAD

1. According to the Effect Produced on the Body:

(i) **Tensile Load :** *The load whose effect is to increase the length of the body in the direction of its application is known as tensile load.* See fig. 2.1(a).

(ii) **Compressive Load** : *The load whose effect is to decrease the length of the body in the direction of its application is known as compressive load.* See fig. 2.1(b).

(iii) **Shearing Load :** *The load whose effect is to cause sliding of one face of the body relative to the other is called shearing load.* In this case, two equal, opposite and parallel forces are applied along the different planes. See fig. 2.1(c).

(iv) **Bending Load :** *The load whose effect is to cause a certain degree of curvature or bending in the body is called bending load.* See fig. 2.1(d).

(v) **Twisting Load :** *The effect produced by two couples applied at opposite ends of the body so as to cause one end to rotate about its longitudinal axis relative to the other end are called twisting loads.* See fig. 2.1(e).

2. According to the Manner of Application of Load on the Body :

(i) **Dead Loads :** These loads are also known as static loads. *Magnitude, direction and point of application of these loads are fixed for a given member.* These loads always act vertically downwards. Dead load on a bridge girder is its own weight, weight of road-way and weight of other permanent fixtures on the bridge.

(ii) **Live Loads :** These loads are also known as fluctuating loads. *Magnitude,. direction and point of application of these loads are not fixed for a given member.*

These loads are further classified as under :

(a) Loads which are always same in nature, but different in magnitude. *e.g.* weight of vehicles crossing over a bridge.

(b) Loads which are applied with velocity. *e.g.* a hammer driving a pin.

(c) Loads which change from a maximum of one kind to maximum of opposite kind. *e.g.* alternate push and pull in the piston rod and connecting rod of a steam engine.

2.4 STRENGTH

The strength of a material may be defined *as the maximum resistance which a material can offer to the externally applied load.* The strength of a material depends upon a number of factors such as type of loading, temperature, internal structure etc. It has been established beyond doubt that the actual strength of the material is much below the theoretical cohesive strength of the material.

2.5 STRESS

When some external forces are applied to a body, it undergoes some deformation. As the body undergoes deformation, its molecules set up some internal resistance to deformation. This internal resistance per unit area to deformation is known as stress. The magnitude of the internal resisting force is numerically equal to the applied forces.

In simple way, we can define stress as *the internal resistance per unit area of cross-section offered by a body against the deformation.*

The stress is denoted by *f*, P or σ (sigma). Mathematically, stress may be defined *as the force per unit area.*

$$\sigma = \frac{P}{A}$$

where σ = Stress induced in the body,

P = Load or force acting on the body,

A = Cross-sectional area of the body.

In S.I. system, stress is expressed in N/m^2, N/mm^2 or kN/m^2. **N/m^2** is also known as **Pascal,** written as Pa. In actual practice, we use bigger units of stress *i.e.* Mega Pascal (MPa) and Giga Pascal (GPa) etc.

$$1\text{ MPa} = 10^6 \frac{N}{m^2} = 1\text{ N/mm}^2$$

$$1\text{GPa} = 10^9 \frac{N}{m^2} = 10^3\text{ N/mm}^2$$

Table 2.1

Multiple Factorah	Prefix	Symbol
10^{12}	Tera	T
10^9	Giga	G
10^6	Mega	M

Multiple Factorah	Prefix	Symbol
10^3	kilo	k
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

2.6 TYPES OF STRESSES

The stresses can be classified into two categories :

1. Direct stress, 2. Shear stress.

1. Direct Stress : *When a force is applied perpendicular to the cross-section of the member, the stress induced is known as direct stress.* Direct stress is also known as normal stress.

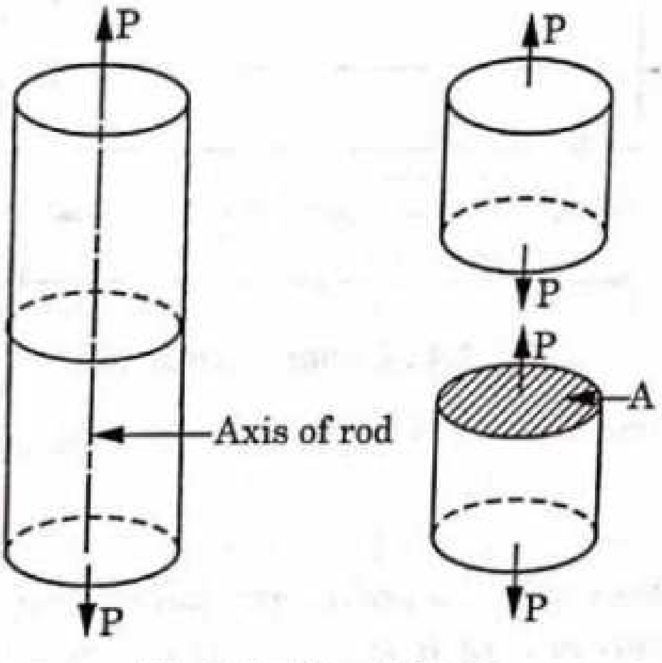


Fig. 2.2 : Direct Stress

The direct stress is either tensile or compressive in nature depending upon the nature of applied force.

(i) **Tensile Stress :** *When an axial pull is applied on the cross-sectional area of a body, the stress induced is known as tensile stress.* The effect of tensile stress is to increase the length of the body. The member subjected to tensile stress is known as tie.

Let an axial pull P is applied on the cross sectional area A of a body so that the length l of the body increases to $(l + \delta l)$ as shown in fig. 2.3.

The tensile stress is given by

$$\sigma_t = \frac{P}{A}$$

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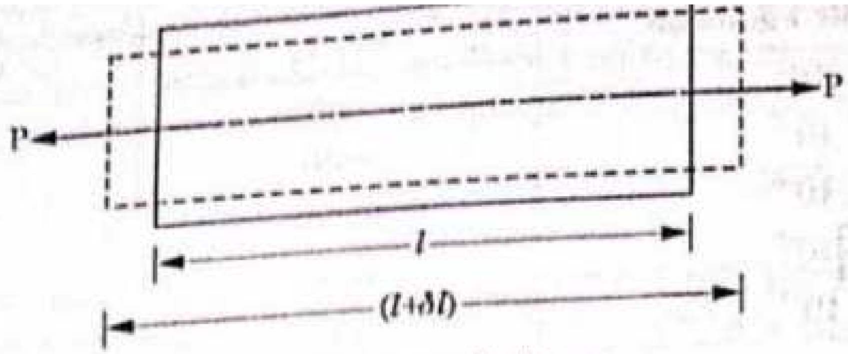

Fig. 2.3 : Tensile Stress

(ii) **Compressive Stress :** *When an axial push is applied on the cross-sectional area of a body, the stress induced is known as compressive stress.* The effect of compressive stress is to decrease the length of the body. The member subjected to compressive stress is known as strut.

Let an axial push P is applied on the cross sectional area A of a body so that the length l of the body is decreased to $(l - \delta l)$ as shown in fig. 2.4.

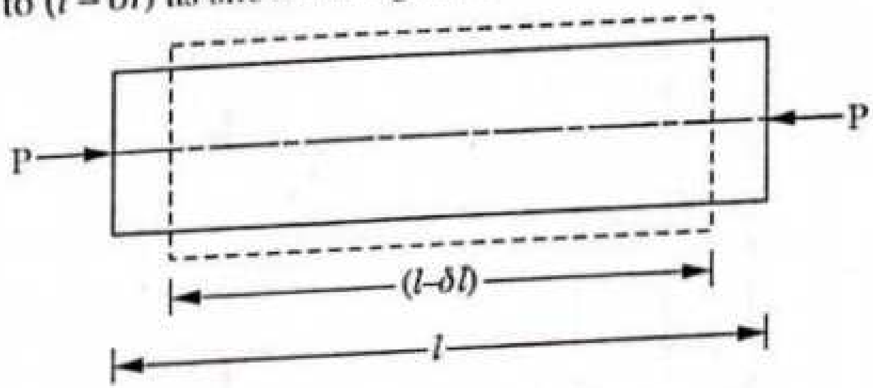

Fig. 2.4 : Compressive Stress

Then compressive stress is given by

$$\sigma_c = \frac{P}{A}$$

2. **Shear Stress :** *When two equal and opposite forces are applied tangentially to the cross section of a body, the stress induced is known as shear stress.* Due to these two equal and opposite forces, the member tends to shear off across the section. The shear stress is also known as tangential stress.

A riveted joint shown in the fig. 2.5 is a typical example where the rivet resists shear across its cross-sectional area A.

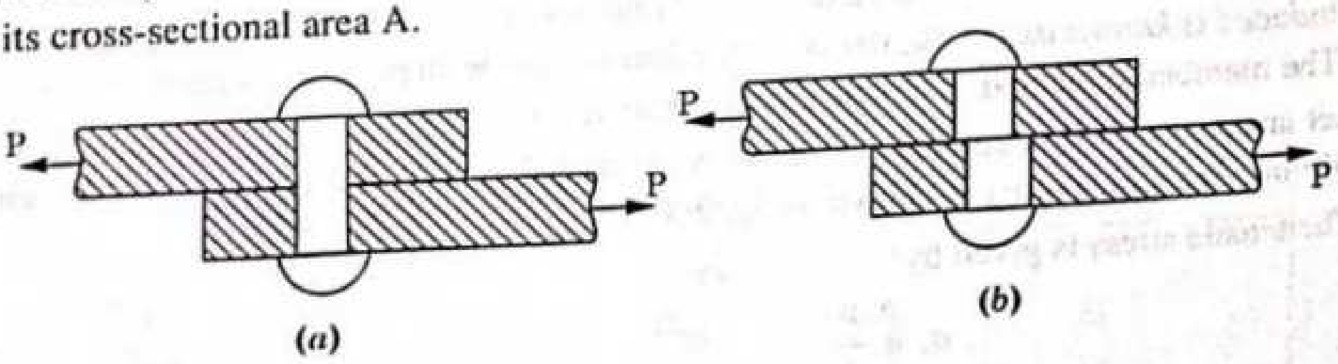

Fig. 2.5 : Riveted Joint Subjected to Shear Stress

Let us consider a block ABCD with bottom face DC fixed to the surface as shown in fig. 2.6. When a force P is applied tangentially to the block, it takes the shape A' B' CD.

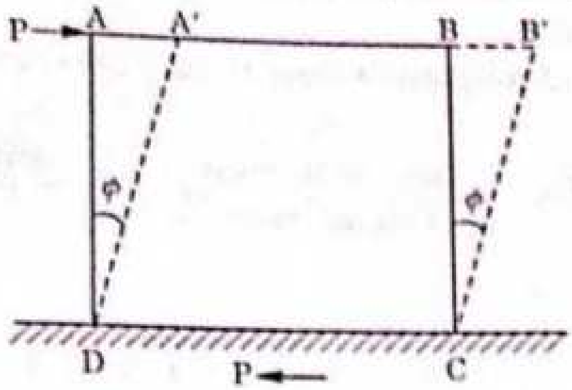

Fig. 2.6 : Shearing of a Block

Let A = Shear area (in the plane perpendicular to the paper).

$$\text{Shear stress, } \tau = \frac{\text{Shear force}}{\text{Shear area}} = \frac{P}{A}$$

2.7 STRAIN

As already mentioned, whenever a single force (or a system of forces) acts on a body, it undergoes some deformation. This deformation per unit length is known as strain. Simply, we can define strain as *the ratio of change in dimension of the body to the original dimension of the body*. Strain in denoted by $\in$ (Epsilon).

$$\therefore \quad \text{Strain, } \in = \frac{\text{Change in dimension}}{\text{Original dimension}}$$

Strain being the ratio of two similar quantities is a pure number. Hence, strain is dimensionless.

2.8 TYPES OF STRAINS

There are four types of strains :

1. Tensile strain, 2. Compressive strain, 3. Shear strain, 4. Volumetric strain.

1. Tensile Strain : When a member is subjected to axial pull on its cross-sectional area, its length increases. *The ratio of increase in the length to the original length of the member is termed as tensile strain.*

Let due to application of tensile force P, the original length l of a member changes to $(l + \delta l)$, then

$$\therefore \quad \text{Tensile strain} = \frac{\text{Increase in length}}{\text{Original length}} = \frac{(l + \delta l - l)}{l}$$

or

$$\in_t = \frac{\delta l}{l}$$

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2. Compressive Strain : When a member is subjected to axial push on its cross-sectional area, its length decreases. *The ratio of decrease in length to the original length of the member is termed as compressive strain.*

Let due to application of compressive force P, the original length l of a member changes to $(l-\delta l)$, then

$$\text{Compressive strain} = \frac{\text{Decrease in length}}{\text{Original length}} = \frac{[l-(l-\delta l)]}{l}$$

or

$$\in_c = \frac{\delta l}{l}$$

3. Shear Strain : When a body is subjected to two equal and opposite parallel forces not in same line, it tends to shear off across the resisting section. As a result, the member distorts as shown in fig. 2.7 from ABCD to ABC_1D_1 through an angle ϕ. *The ratio of angular deformation to original length along the force is termed as shear strain.*

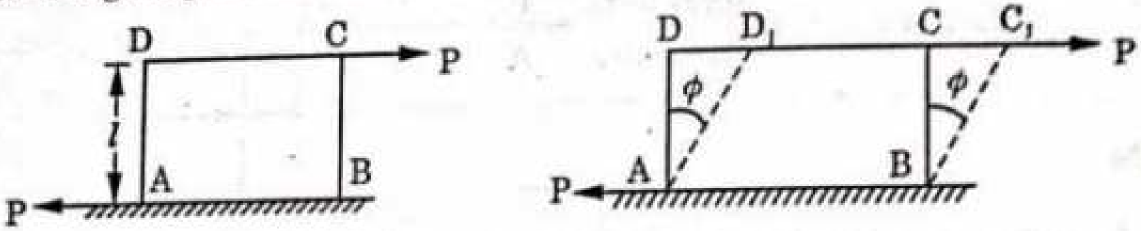

Fig. 2.7 : Shear Strain

$$\therefore \quad \text{Shear strain, } \in_S = \frac{CC_1}{BC} = \tan\phi = \phi \qquad (\because \phi \text{ is small, so } \tan\phi = \phi)$$

4. Volumetric Strain : *The ratio between the change in volume and the original volume of a member is known as volumetric strain or bulk strain.*

$$\therefore \quad \text{Volumetric strain, } \in_V = \frac{\text{Change in volume}}{\text{Original volume}}$$

$$\in_V = \frac{\delta V}{V}$$

SHEAR FORCE AND BENDING MOMENT

3.1 BEAM

A beam is a structural member which can take loads acting at right angles to its longitudinal axis. Generally, a beam is a horizontal member of moderate size and is made up of one piece.

3.2 TYPES OF END SUPPORTS OF BEAMS

The followings are the important types of supports of beams :

1. Free support,
2. Hinged support,
3. Roller support,
4. Fixed support.

1. Free Support : *When the beam rests freely on the support, the support is known as free support or simple support.* These supports are in the form of walls or columns. The reaction at the free support always acts vertically upwards. The free supports are shown in fig. 3.1 by points A and B. The reactions at the supports are normal to the supports and are represented by R_A and R_B respectively.

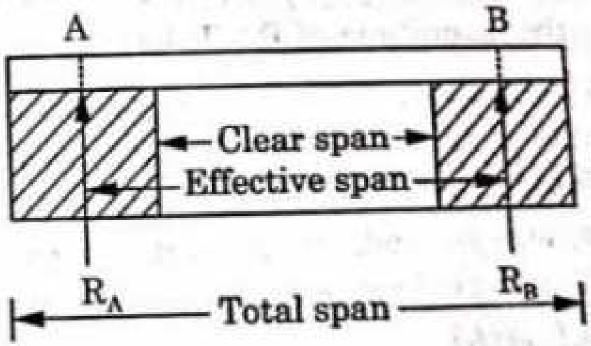

Fig. 3.1 : Free Support

2. Hinged Support: The beam supported on hinged support can rotate about hinge, but cannot move sideways, thus the position is fixed. *The reaction on a hinged support may be either horizontal or vertical or inclined depending upon the type of loading on the beam.* (See fig. 3.2)

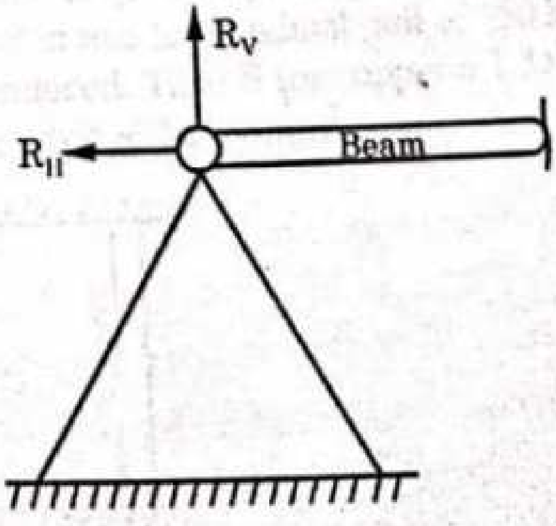

Fig. 3.2 : Hinged Support

3. **Roller Support :** *The support in which the beam is free to move in horizontal direction is called roller support.* The beam supported on roller support is free to move to the right or left of it. Roller reaction is always perpendicular to the roller base. (See fig. 3.3).

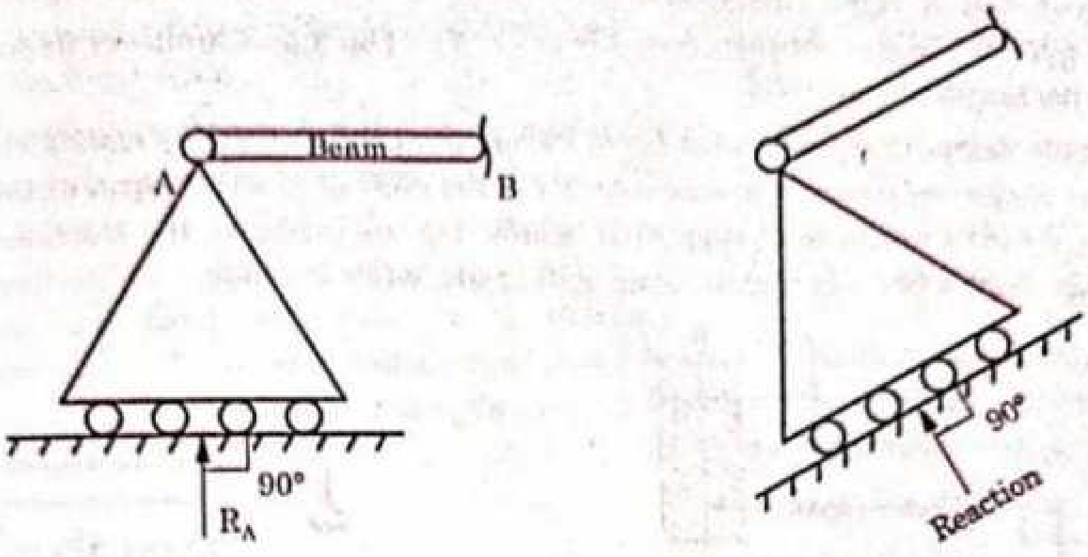

Fig. 3.3 : Roller Support

4. **Fixed Support:** *The support in which the beam is fixed in position as well as in direction is called fixed support.* Thus fixed support does not allow either lateral movement or the rotation of the beam.

In a fixed support, there are horizontal and vertical reactions and fixing moment. *When the loads are vertical on a horizontal beam, then only vertical reaction and fixing moment are developed on a fixed support.* (See fig. 3.4)

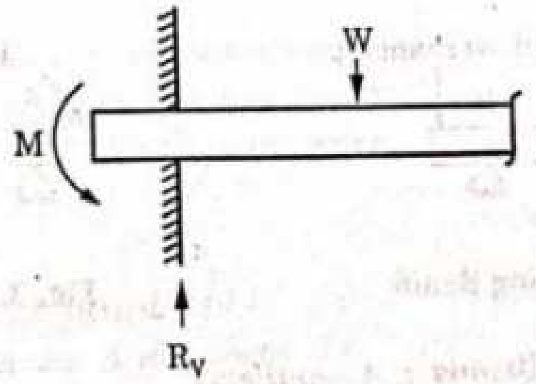

Fig. 3.4 : Fixed Support

3.3 CLASSIFICATION OF BEAMS

The beams may be classified in several ways, but the commonly used classification is based on end conditions. On this basis, the beams can be divided into six types :

1. Cantilever beams,
2. Simply supported beams,
3. Overhanging beams,
4. Propped cantilever beams,
5. Fixed beams,
6. Continuous beams.

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1. **Cantilever Beams :** *A beam having one end fixed and the other end free is known as cantilever beam.* Fig. 3.5 shows a cantilever with end A rigidly fixed and the other end B free. The length between A and B is known as the length of cantilever.

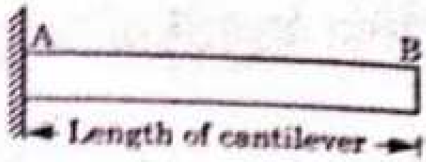
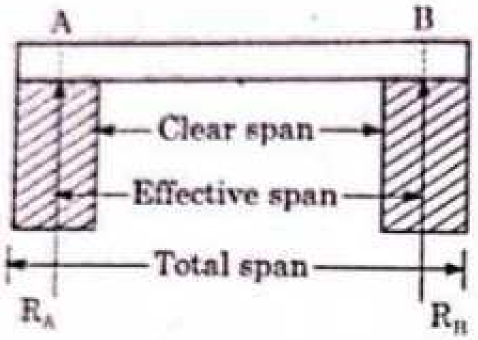
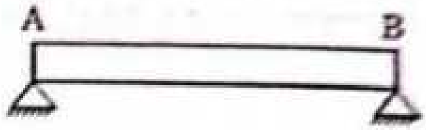


Fig. 3.5 : Cantilever Beam

2. **Simply Supported Beams :** *A beam having both the ends freely resting on supports is called a simply supported beam.* The reactions act at the ends of effective span of the beam. Fig 3.6(*a*) and fig. 3.6(*b*) show simply supported beams. For such beams, the reactions at the two ends are vertical. Such a beam is free to rotate at the ends, when it bends.



(*a*)



(*b*)

Fig. 3.6 : Simply Supported Beam

3. **Overhanging Beams :** *A beam for which the supports are not situated at the ends and one or both ends extend over the supports is called an overhanging beam.* Fig. 3.7 and fig. 3.8 represent overhanging beams.

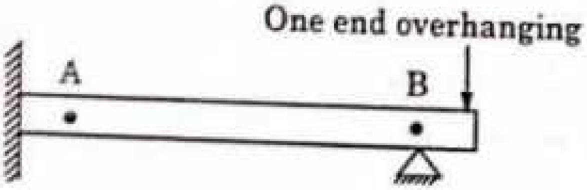


Fig. 3.7 : Overhanging Beam

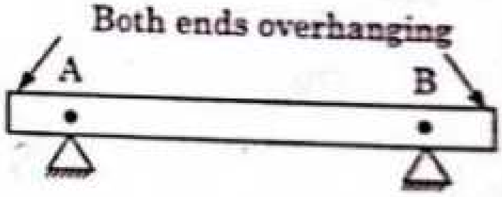


Fig. 3.8 : Overhanging Beam

4. **Propped Cantilever Beams :** *A cantilever beam of which one end is fixed and other end is provided with support in order to resist the deflection of the beam is called a propped cantilever beam.* A propped cantilever is a statically indeterminate beam. Such beams are also known as restrained beams as an end is restrained form rotation. (See fig. 3.9).

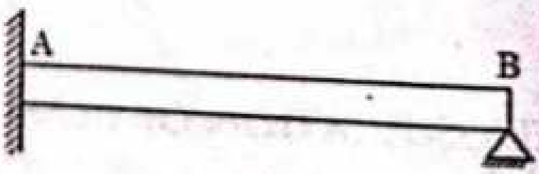


Fig. 3.9 : Propped Cantilever Beam

5. Fixed Beams : *A beam having its both the ends rigidly fixed against rotation or built into the supporting walls is called a fixed beam.* Such a beam has four reaction components for vertical loading (*i.e.* a vertical reaction and a fixing moment at both ends) Fig. 3.10 shows the fixed beam.

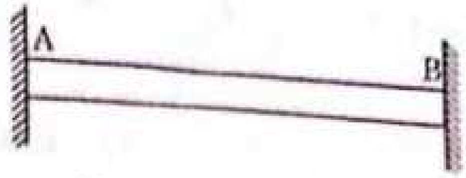


Fig. 3.10 : Fixed Beam

6. Continuous Beam : *A beam having more than two supports is called a continuous beam. The supports at the ends are called end supports, while all the other supports are called intermediate supports.* It may or may not have overhangs. It is statically indeterminate beam. In these beams, there may be several spans of same or different lengths. Fig. 3.11 shows a continuous beam.

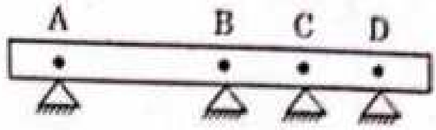


Fig. 3.11 : Continuous Beam

3.4 TYPES OF LOADS

A beam may be loaded in a variety of ways. For the analysis, it may be splitted in three categories :

1. Concentrated or point load .
2. Distributed load :
   (*i*) Uniformly distributed load,
   (*ii*) Uniformly varying load.
3. Couple.

1. Concentrated Load : *A concentrated or point load is one which acts over so small area that it is assumed to act at a point.* Fig. 3.12 represents point loading at points A and B.

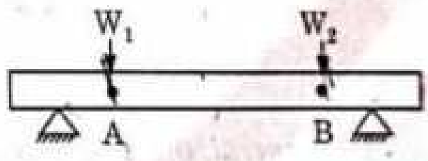


Fig. 3.12 : Concentrated Load

2. Distributed Load : *A distributed load acts over a finite length of the beam. A distributed load may be uniform over the length or it may vary uniformly or non-uniformly.* Such loads are measured by their intensity which is expressed by the force per unit distance along the axis of the beam. Fig. 3.13 represents distributed loading between points A and B.

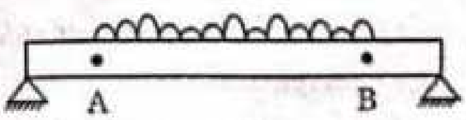


Fig. 3.13 : Distributed Load

(*i*) **Uniformly Distributed Load :** *A uniformly distributed load implies a constant intensity of loading along the length.* It is generally abbreviated as U.D.L. and its unit is kN/m. Fig. 3.14 represents a U.D.L. between points A and B.

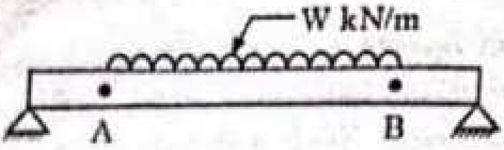


Fig. 3.14 : Uniformly Distributed Load

(ii) Uniformly Varying Load : *A uniformly varying load implies that the intensity of loading increases or decreases at a constant rate along the length.*

$$W = W_0 + K x$$

where K is the rate of change of intensity of loading, W_0 being the loading at the reference point.

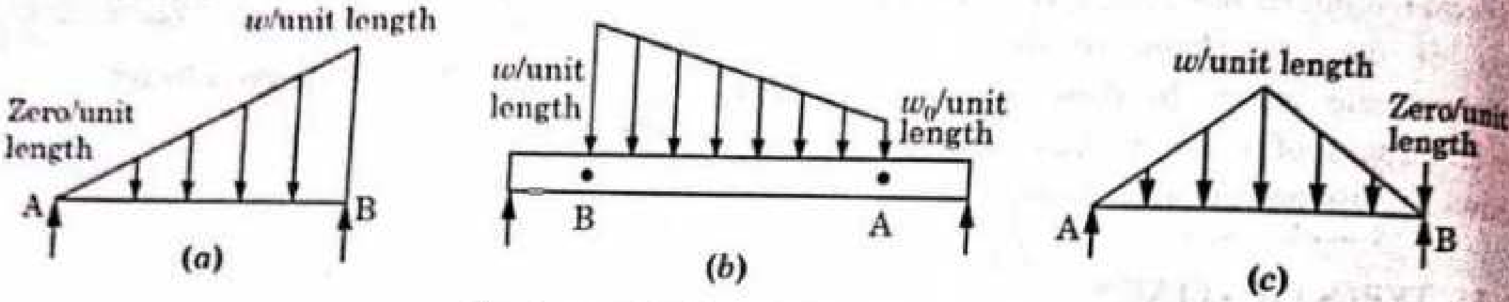


Fig. 3.15 : Uniformly Varying Load

Such a loading is also known as triangularly distributed load. Fig. 3.15 represents such a loading between points A and B.

3. **Couple :** A beam may also be subjected to a couple 'μ' at any point as shown in fig. 3.16

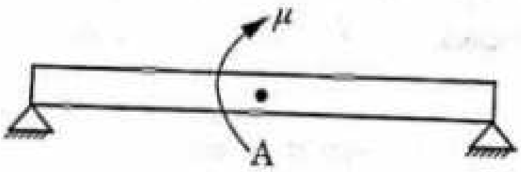


Fig. 3.16 : Couple

Note : *In general, the load may be a combination of various types of loadings.*

3.5 SHEAR FORCE (S. F.)

Shear force at any section of a beam may be defined as *the algebraic sum of all the vertical loads acting on the beam on either side of the section under consideration.*

Sign Convention :

(i) *Upward loads to the left of a section or downward loads to the right of it are considered as positive.*

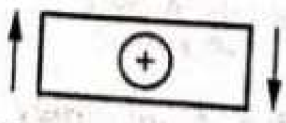


Fig. 3.17 : Positive Shear Force

(ii) *Downward loads to the left of a section or upward loads to the right of it are considered as negative.*

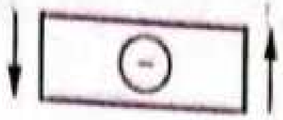


Fig. 3.18 : Negative Shear Force

3.6 BENDING MOMENT (B.M.)

The bending moment at any section of a beam may be defined as *the algebraic sum of moments of all the vertical loads (acting either to the left or to the right of the section) about that section.*

Sign Convention :

(i) *The bending moment producing convexity downwards is known as positive bending moment.* The positive B.M. is also known as sagging bending moment. Upward loads on either side of a section produce sagging or positive bending moment as shown in fig. 3.19.

(Convexity downwards)

Fig. 3.19 : Positive Bending Moment

(ii) *The bending moment producing convexity upwards is known as negative bending moment.* The negative B.M. is also known as hogging bending moment. Downward loads on either side of a section produce hogging or negative bending moment as shown in fig. 3.20.

(Convexity upwards)

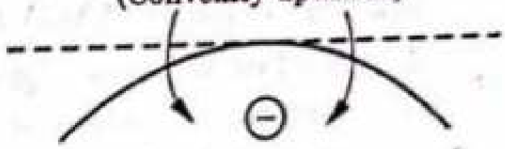


Fig. 3.20 : Negative Bending Moment

3.7 SHEAR FORCE DIAGRAM (S.F.D.)

The shear force diagram (S.F.D.) represents the variation of shear force along the length of beam. The positive shear force is plotted as ordinate above arbitrary reference line and negative shear force below it. The straight lines or curves joining the tips of all such ordinates at salient points form the S.F.D.

3.7.1 Steps To Draw An S.F.D.

The steps to draw an S.F.D are as follow :

1. Draw the symbolic loading diagram of the given beam to some scale along the length of the beam .
2. Find the reactions at the supports using equations of equilibrium.
3. Starting form the right end, obtain the shear force at various sections and at all salient points.

4. If there is no loading between two sections, the shear force will not change between these sections.
5. Plot the S.F.D. to a suitable scale under the loading diagram with the same scale along the length.

3.7.2 Special Features of S.F.D.

1. It consists of rectangles for point loads.
2. It consists of an inclined line for the portion on which U.D.L. is acting.
3. It consists of a parabolic curve for the portion over which uniformly varying load acts.
4. It may be a cubic or higher order curve depending upon the type of distributed load.

3.8 BENDING MOMENT DIAGRAM (B.M.D.)

The bending moment diagram (B.M.D.) represents the variation of bending moment along the length of a beam. The positive B.M. is plotted above the arbitrary reference line, while the negative bending moment is drawn below it and a line joining the extremities of the ordinates at salient points form B.M.D.

3.8.1 Steps To Draw A B.M.D.

The steps to draw a B.M.D. are as follow:

1. Starting form the right hand end of the beam for convenience, obtain the bending moment at various sections in magnitude and direction. The B.M. at a section is obtained by the summation of the moments due to the reactions and other forces acting on the right hand side only or on the left hand side only.
2. Determine the B.M. at all salient points. At these points, the B.M. changes in magnitude or sign.
3. Plot the B.M.D. to a suitable scale preferably under the loading diagram and S.F.D. using straight lines or smooth curves as applicable.

3.8.2 SPECIAL Features of B.M.D.

1. It consists of inclined lines for the beam loaded with point loads.
2. It consists of a parabolic curve for the portion over which *u.d.l.* is acting.
3. It consists of a cubic curve for uniformly varying load.
4. It consists of a higher degree curve for distributed loading.

3.9 RELATION BETWEEN LOAD, SHEAR FORCE AND BENDING MOMENT

The following relations between load, shear force and bending moment at a point or between any two sections of a beam are important :

1. If there is a point load at a section on the beam, then shear force suddenly changes *i.e.* shear force line is vertical, but bending moment remains same.
2. If there is no load between two points on the beam, then shear force does not change *i.e.* shear force line is horizontal, but bending moment changes linearly *i.e.* bending moment line is an inclined straight line.
3. If there is a uniformly distributed load between two points on the beam, then shear force changes linearly *i.e.* shear force line is an inclined straight line, but bending moment changes according to parabolic law *i.e.* bending moment line is a parabola.
4. If there is a uniformly varying load between two points on the beam, then shear force changes according to parabolic law *i.e.* shear force line will be a parabola, but bending moment changes according to cubic law.

ANALYSIS OF TRUSSES

10.1 TRUSS

A skeleton made of a number of bars connected together is known as a truss or a framed structure or simply a frame.

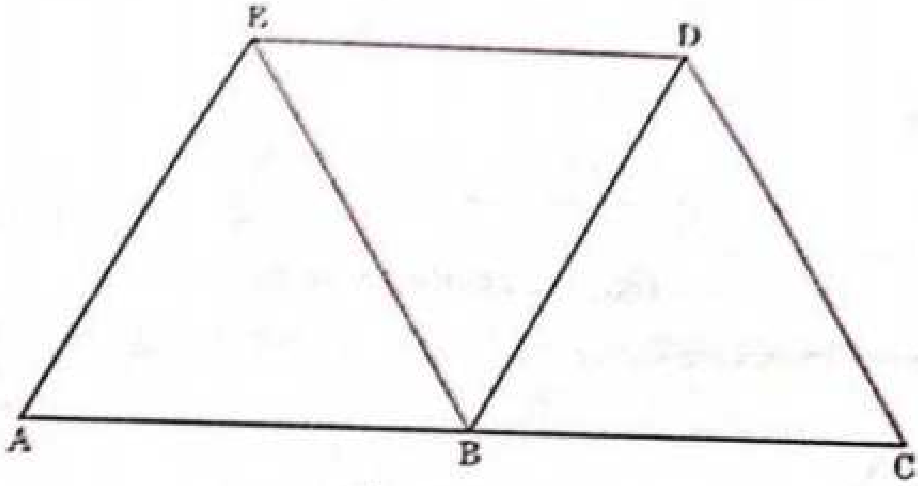


Fig. 10.1 : Truss

The bars known as members of the truss may be in the form of rectangular plates, circular rods, angles, rolled steel joists, channels etc. These members are connected at joints by means of pins, bolts, rivets etc. Whatever may be the type of connection, for simplicity of calculations, all types of joints are assumed as pin jointed. In fig. 10.1, AB, BC, CD, DB, DE etc. are the members of the given frame and A, B, C, D, E etc. are joints.

Trusses are used for roofs in industrial buildings, workshops and other large span buildings due to economy, ease of manufacture and light in weight.

10.2 TYPES OF FRAMES

Depending upon the relationship between the number of members and number of joints in a framed structure, there are three types of frames:

1. Perfect frames,
2. Deficient frames,
3. Redundant frames.

Deficient frames and redundant frames are also known as imperfect frame.

1. Perfect Frame: *If the number of members in a frame are just sufficient to keep it in equilibrium, it is said to be a perfect frame.* A perfect frame is statically determinate, which means that the forces in various members can be found by the equations of equilibrium ($\Sigma V = 0$, $\Sigma H = 0$, $\Sigma M = 0$).

For a perfect frame, $n = 2j - 3$

Where n = Number of members in the frame,

j = Number of joints in the frame.

Fig. 10.2 shows a frame having 3 members and 3 joints. It is a perfect frame because relation ($n = 2j - 3$) is satisfied.

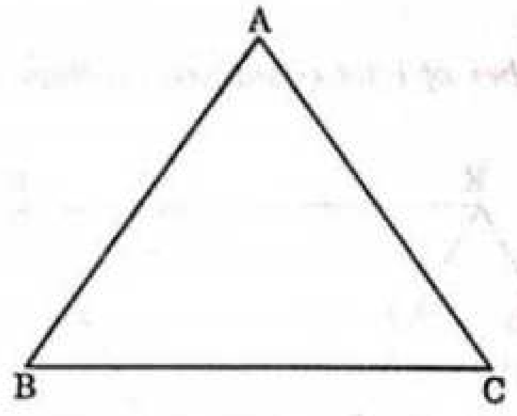


Fig. 10.2 : Perfect Frame

Some other perfect frames are shown in fig. 10.3 (*a*), 10.3 (*b*) and 10.3 (*c*).

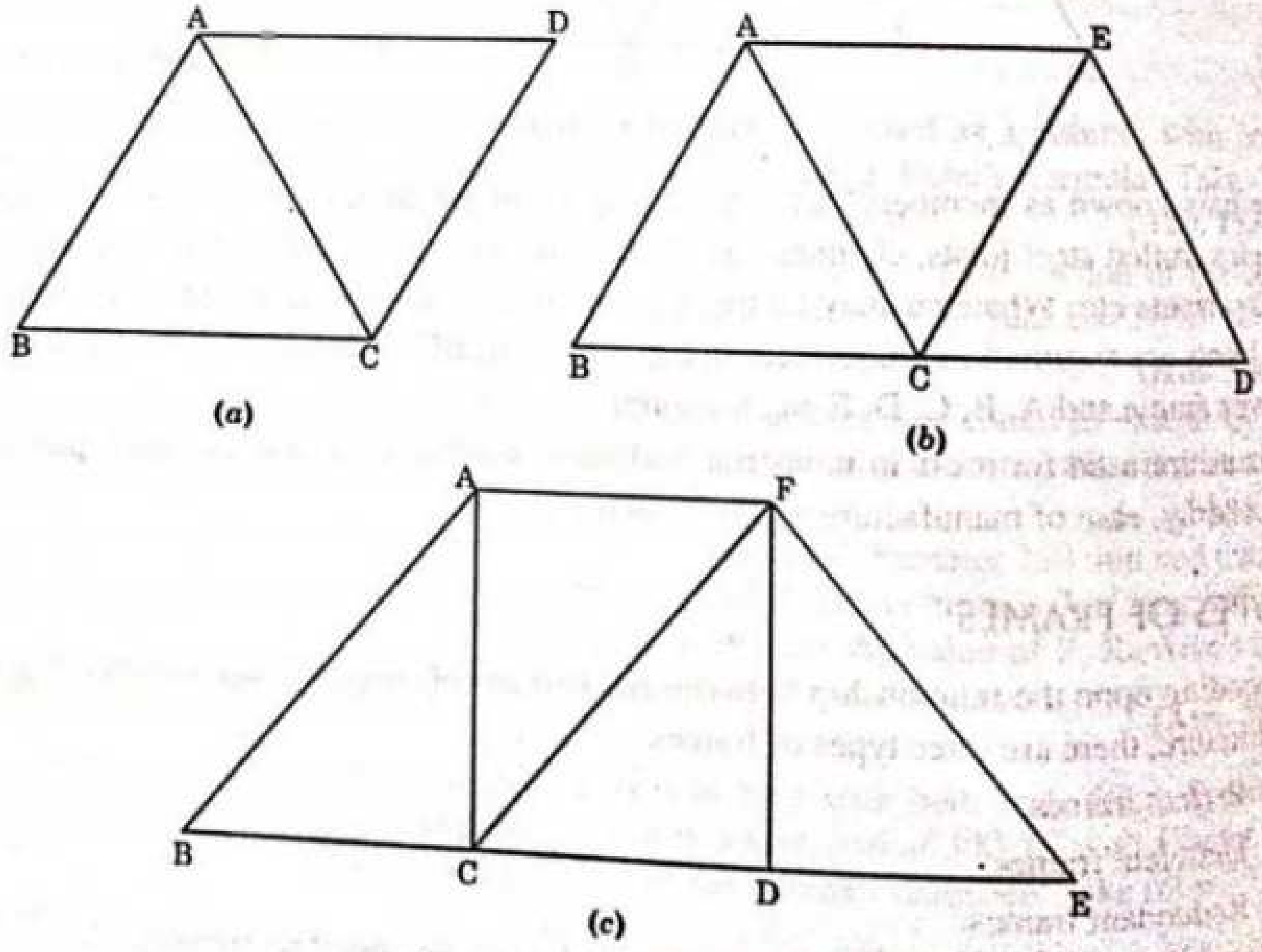


Fig. 10.3 : Perfect Frames

Scanned with CamScanner

2. **Deficient Frame:** *If the number of members in a frame are less than (2j – 3), then the frame is known as deficient frame.* Deficient frames are unstable. Fig. 10.4 shows a deficient frame.

Here $n = 8$ and $j = 6$

and $n < (2j - 3)$

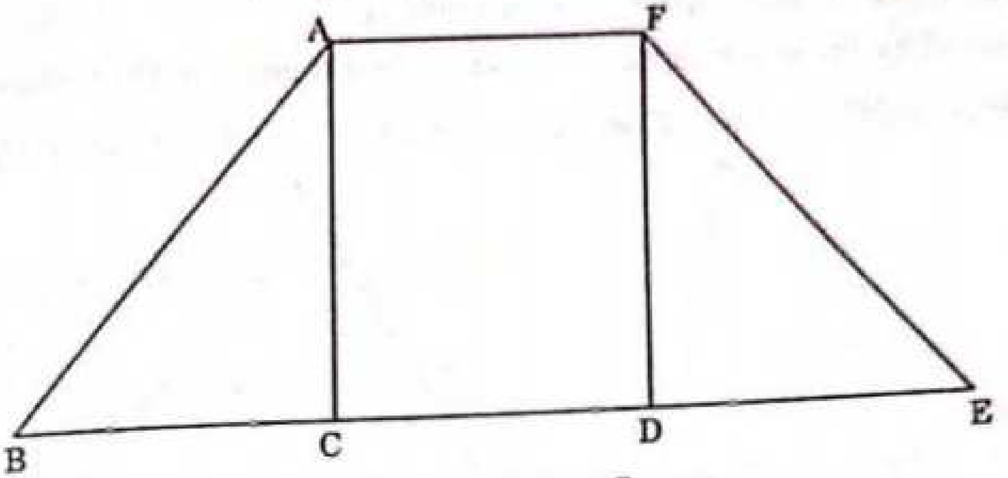


Fig. 10.4 : Deficient Frame

3. **Redundant Frame:** *If the number of members in a frame are greater than (2j – 3), then the frame is known as redundant frame.* Redundant frame is also known as statically indeterminate frame, which means that the forces in various members cannot be found out by the equations of equilibrium only. Fig. 10.5 shows a redundant frame.

Here $n = 10$ and $j = 6$

and $n > (2j - 3)$

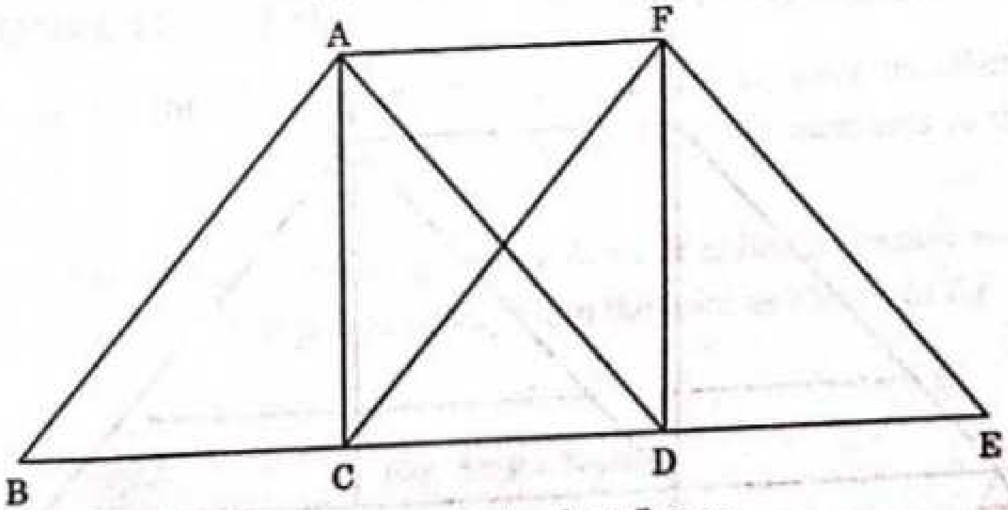


Fig. 10.5 : Redundant Frame

10.3 TYPES OF SUPPORTS FOR TRUSSES

The kind and nature of support is very important to find out the forces in various members of the framed structure. The end supports are also helpful in finding out the nature of reactions. In case of framed structures, the supports are classified as follow:

1. Free support or roller support,

2. Hinged support.
3. Fixed support.

1. **Free Support or Roller Support:** In this case, the ends of the frame are supported on rollers. The ends are free in direction as well as in position. The roller ends can move in horizontal direction. Horizontal movement of the roller support is caused either due to inclined loads acting on the frame or due to temperature variations.

Reaction caused by the roller support is always at right angle to the surface on which roller rests.

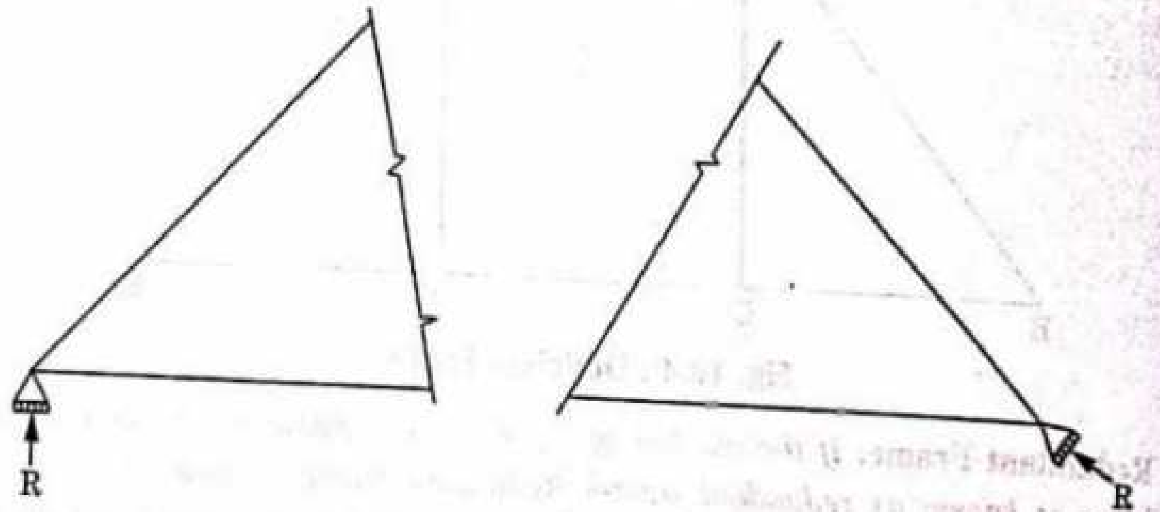


Fig. 10.6 : Roller Supports

If rollers are provided on both the ends, then there will be no equilibrium of frame in horizontal direction. For maintaining equilibrium, at least one end of the frame has to be hinged as shown in fig. 10.7.

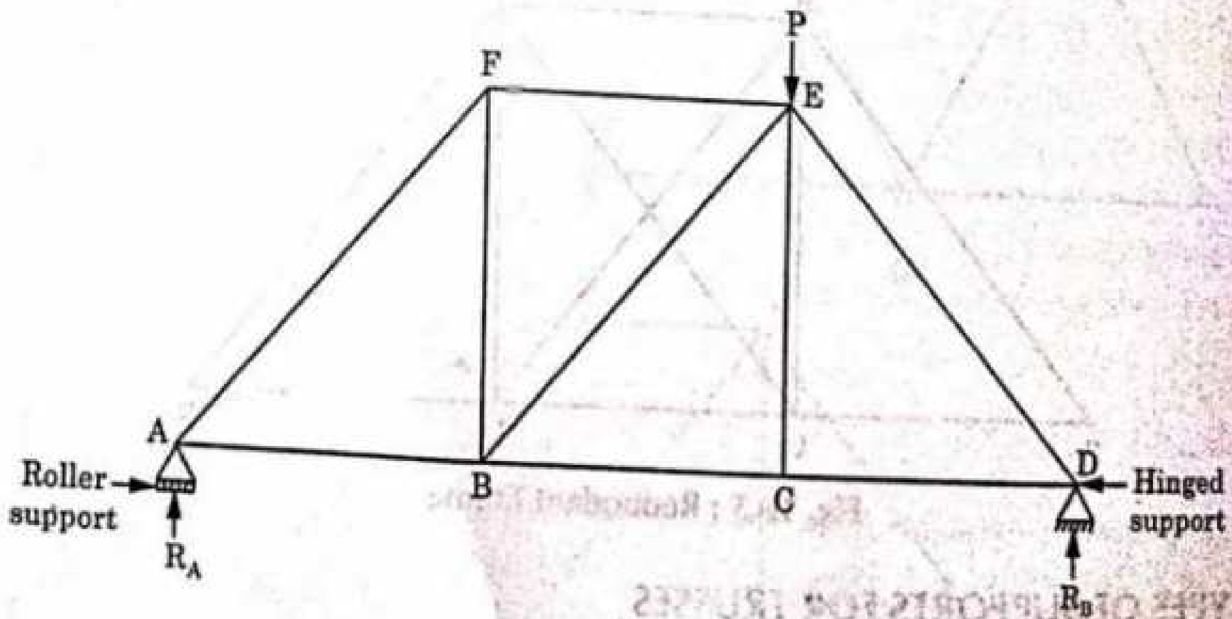


Fig. 10.7

2. **Hinged Support:** In this case, the ends of the frame are pin jointed to the supporting base. In such cases, the position is fixed but not the direction. The frame is capable of taking horizontal as well as vertical loads. The hinge permits rotation but does not permit horizontal

movement of the frame. Reaction at the hinge may or may not be vertical. It will depend upon the load system on the frame. If only vertical loads are acting on the frame, then the reaction at the hinge will be vertical. But if the horizontal or inclined loads are acting on the frame, then the reaction at the hinge will be horizontal or inclined.

3. **Fixed Support:** In this case, the ends of the frame are fixed in direction as well as in position. The horizontal as well as vertical reactions and moments are induced at the fixed support.

10.4 ASSUMPTIONS FOR DETERMINING FORCES IN VARIOUS MEMBERS OF A TRUSS

The following assumptions are made for determining the forces in various members of a framed structure:

1. All the joints of the truss are hinged or pin-jointed. It means that no moment is possible at any joint.
2. All the external loads and even the self weight of the member (if considered) are supposed to act on the joints of the framed structure.
3. The members of the truss are subjected to either direct tension or direct compression only. They are not subjected to any bending moment.
4. The frame is a perfect frame and all the members of the frame lie in one plane.
5. There is no change in length of an individual member of the truss.

10.5 SIGN CONVENTIONS FOR TENSION AND COMPRESSION MEMBERS

When a framed structure is subjected to loads at the joints, some members are under tension and some members are under compression. There can be some members in the framed structure which have zero force.

Tension Member: *A member having tensile force is called a tension member or a tie.* In a tension member, arrow is marked pointed away from the joint as shown in fig. 10.8.

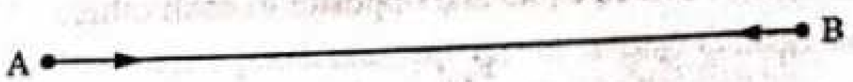


Fig. 10.8 : Tension

Compression Member: *A member having compressive force is called a compression member or a strut.* In a compression member, arrow is marked pointed towards the joint as shown in fig. 10.9.

Fig. 10.9 : Compression

10.7 METHODS OF DETERMINING FORCES IN VARIOUS MEMBERS OF A TRUSS

The following three methods are used for determining forces in various members of a truss:

1. Method of joints.
2. Method of sections.
3. Graphical method.

10.8 METHOD OF JOINTS

The following steps should be followed for analysis of a truss by method of joints:

1. Calculate the reactions at the supports by considering external loads and applying three conditions of equilibrium *i.e.* $\Sigma V = 0$, $\Sigma H = 0$ and $\Sigma M = 0$.
2. Now consider any joint of the truss having not more than two unknown forces.
3. Assume the direction of unknown forces in the members at the joint under consideration.
4. Resolve all the forces into horizontal and vertical components. Applying the equations of statics *i.e.* $\Sigma V = 0$ and $\Sigma H = 0$ at the joint, find the values of the unknown forces in the various members.
5. If the force in any member comes out to be negative, it indicates that the assumed direction of the force in the particular member is wrong. Change the assumed direction of the force in that member.
6. Now move to the next joint having maximum two unknown forces and solve in the same manner. This process is carried on till the forces in all the members are known.
7. In case of cantilever trusses, start from the free end.